*High-Speed Motion Pictures in Wood Research**

WILFRED A. COTE, JR., *Instructor in Wood Technology, State University of New York, College of Forestry, Syracuse, New York*

SUMMARY: *High-speed motion picture photography can be a useful tool in the various fields of wood research. It provides a means of seeing action that is too rapid for the human eye to perceive. A magnification of time as great as 1,000 can be achieved by projecting films at standard speed that have been exposed at the maximum rate of 16,000 frames per second. Some aspects of the machining and the mechanical testing of wood have been studied through the use of the high-speed motion picture camera. A description of the equipment, methods of operation and application to specific studies is given. Illumination, synchronization of the camera with the event, and other general problems are discussed.*

INTRODUCTION

RESEARCH in wood offers many opportunities for using a tool which is new to this field: high-speed motion picture photography. Many tests and operations performed with wood involve the use of equipment which does the job very rapidly. As a result, a great deal of the information which is available in wood-using industries is based on the condition of the finished product after machining or testing and on some intelligent theorizing which follows the examination of the piece of wood. The eye is unable to follow high-speed action to observe the work or test in process. Photography can now provide this observation in many instances.

In addition to qualitative information, the high-speed motion picture camera can also provide quantitative data. The engineer or designer can determine the speed of operation of a piece of machinery or the rapidity of an event by counting the number of frames between timing marks on the film and by studying the individual frames.

PRINCIPLE OF HIGH-SPEED MOTION PICTURES

The idea behind high-speed motion picture photography is by no means new. Basically, it is nothing more than slow-motion photography on a greatly exaggerated scale. When ordinary movies are made, the film is exposed at either 16 or 24 pictures per second. When these are projected, the same speed is used to recreate the action at normal speed. In photographing athletic events, or for some other specialized use, the slow-motion principle is frequently employed. This consists simply of photographing the event at a greater than normal rate of speed and then projecting the film at standard speed. Sixty-four frames per second is the usual slow-motion taking speed. This slight time magnification allows the eye to follow details of the action for a longer period than it could otherwise.

High-speed movies are made at a rate of 1,000 or more pictures per second. The equipment used in connection with our studies allows a picture-taking rate as high as 16,000 per second. A time magnification of as much as 1,000 can be achieved when films exposed at maximum speed are projected at 16 frames per second.

DESCRIPTION OF EQUIPMENT

At the College we use a Wollensak Fastax 8 mm. camera in our high-speed studies. This model has a film capacity of 100 feet and a speed range of 300 to about 16,000 frames per second. It can be operated with either AC or DC voltage, DC being necessary at speeds below 1,000 frames due to the torque characteristics of the motors. For low picture-taking rates (below 1,000), storage batteries can be used as the DC source allowing portability for field work.

* Forest Products Research Society, Eastern Canadian Section, Third Annual Meeting, Ottawa, March 14, 15, 16, 1955.

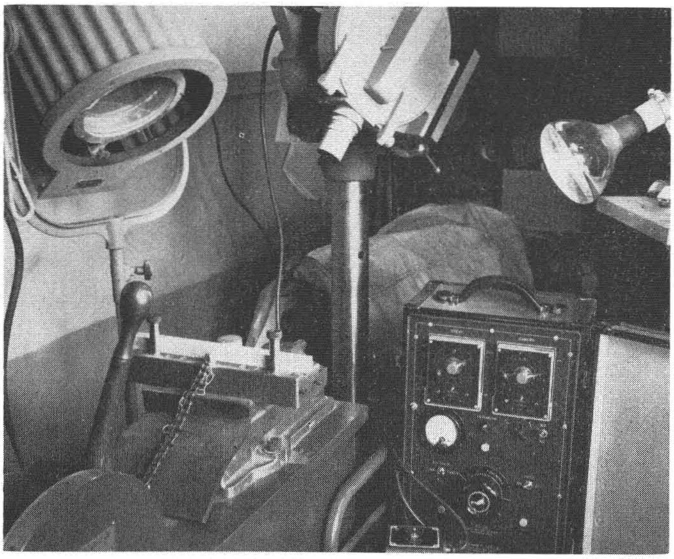

FIG. 1. High-speed motion picture equipment set up to photograph the action in the U. S. Forest Products Laboratory toughness test.

One-hundred-foot rolls of 16 mm. film are normally used, the spool being reversed at the end of the first run and then the other side of the film exposed. After processing, the film is slit to 8 mm. width for projection. The 8 mm. Fastax is supplied with two sizes of aperture plates, the standard 8 mm. and a double-width 8 mm. When the latter is used, the full 16 mm. width of film is exposed providing a wide, narrow field which is well adapted to some types of subjects. Of course, the use of this aperture plate obviates the possibility of two runs on a 100-foot roll of 16 mm. film.

A neon glow lamp is mounted inside the camera and focused onto the edge of the film. A line is connected to it to supply 115-volt, 60-cycle current. As the film runs through the camera, 120 pips per second are exposed along its edge outside the picture area. These timing marks may be used in determining the taking speed which must be known if quantitative data are desired.

The camera's speed is controlled by the input voltage to the driving motors. One of the motors drives the take-up spindle while the other powers the sprocket and a rotating prism. The prism is eight-sided in the 8 mm. model and serves as the shutter. It is located between the lens and the sprocket over which the film runs. As previously mentioned, AC voltage cannot be used to operate the Fastax 8 mm. Camera at speeds below 1,000 frames per second. This lower voltage limit is a little less than 40 volts. There is also an upper voltage limit above which special control equipment must be used. This is about 140 volts which will operate the camera at a rate of 10,000 pictures per second. A Wollensak "Goose" Control Unit is used in the supply line for providing voltages between 140 and 280 and for synchronizing camera operation with electrically operated subjects. A 70-millisecond delay circuit in the unit allows the voltage to be raised safely to the maximum in order to drive the camera at a top speed of 16,000 frames per second.

METHOD OF USE

ILLUMINATION

In high-speed photography, lighting is particularly critical. This is mainly due to the fact that the reciprocity effect which holds for ordinary photography cannot be followed in this specialized field. As a result, exposures are best determined by trial runs for the specific emulsion being used. A special exposure meter for high intensity light may be used for approximate readings, and adjustments in exposure made after viewing the early results.

Very high light intensities are required, particularly at the faster picture-taking rates. This light is supplied by focusing spotlights equipped with water cells and by reflector spotlights designed for intermittent use. Where the subject is flammable or otherwise affected by heat, adequate ventilation and cooling facilities are necessary. Convenient electrical outlets wired with sufficiently heavy lines and properly fused are essential for trouble-free operation. Wherever possible separate lines should be available for camera and lighting equipment.

"Hi-Lo" switches are an integral part of the lighting equipment. These are parallel-series switches which permit the operator to use the lights on low intensity for focusing. This feature saves bulbs and also prevents excessive heating of the subject. The switches are generally placed near the camera so that the operator may switch to high intensity for the few seconds of the camera run.

CAMERA SUPPORT

A good sturdy stand for the camera is as essential for high-speed motion picture photography as it is for other types of photography. Since the Fastax is a heavy piece of equipment (25 lbs.), an ordinary tripod is not adequate. Tripods and stands built especially for this use may be obtained. The Kodak High-Speed Camera Stand, the one we use, provides safe and vibration-free support. With it, the camera can easily be raised or lowered, tilted or turned without disturbing any of the other equipment already set up. It also allows space for the lights to be moved in closely. In certain crowded conditions, this can be quite a problem.

FOCUSING, LOADING, SHOOTING

After the camera and lights have been placed in approximately correct position, the subject is centered in the viewer. With the lights on at low intensity any glare problems can be detected through the viewfinder and the lights moved to correct them. Focusing is done through the taking lens by means of a prism and viewfinder which are mounted on the camera door. When the door is closed, the prism is located on the optical axis of the camera. A light trap is built into the viewer and must be closed by means of a lever before operating the camera.

Camera loading is very simple. The film is threaded over only one sprocket. A hold-down roller must be raised to do this and the camera cannot be closed unless the roller is lowered. The loss of much film and damage to the camera is avoided by the inclusion of this feature in the design. If the focus has to be checked after the camera has been loaded, a hole must be punched in the film. We find it easier to re-load than to do this.

When all of these details have been taken care of, the operator merely turns the lights to high intensity and depresses the camera switch. The switch should be turned off immediately at the end of the run and the lights turned to low intensity or off. This routine is for the photographing of continuous or repetitive action. If the action is of short duration, it must be started at the exact moment to ensure synchronization of the camera with the event. When the "Goose" is used, synchronization is virtually automatic since the timers can be adjusted to start the camera, start the event, stop the event and stop the camera with any desired amount of delay between steps. Various other combinations of adjustments can be used with the "Goose" even to starting the whole sequence with a remote control switch.

APPLICATIONS

There are numerous possibilities for the application of this tool in the various specializations of research in wood and related subjects. Thus far, the camera has been used on three types of problems at the College. The largest amount of work has been done on the machining of wood with the emphasis placed on jointing operations. Considerable work has been done on timber testing and some exploratory runs were made on insect studies. It has been suggested that high-speed studies of sheet formation on a Fourdrinier paper machine might yield interesting results. Possible new uses of high-speed photography are being sought in order to make the original investment in equipment pay good returns. The data which are collected from these high-speed motion pictures are invaluable to the researcher while the films themselves are excellent visual aids for teaching.

When the results of our early high-speed studies of wood machining were shown to people in the wood-using industries, many of them remarked that they learned very little from them that was new. However, they did admit that they saw many things they had always wanted to see but which could only be theorized about prior to the showing of these films.

It should be brought out that certain difficulties will beset those who attempt to use equipment of this type in their own work on wood machining. First of all, it isn't always easy to place the camera in a position to see the action to be photographed. Production machinery isn't designed with this thought in mind. It may be necessary to remove covers and otherwise adapt the equipment for this particular purpose. If the action takes place within a recessed area, illumination can be a serious problem. The results will depend in part on the ingenuity of the photographer in getting light of sufficient intensity upon the subject. Mirrors and condensing lenses are useful accessories for problem subjects.

When wood chips or shavings are showered about the picture area, a directed stream of air or adequate suction must be used to remove them. Otherwise, the event being photographed will be partially or completely obstructed.

In some cases we are faced with the problem of insufficient camera speed to really slow down the action. Such is the case in photographing a circular saw of rather large diameter. The rpm's, generally considered to be the speed rating of a machine, do not provide the whole answer. Peripheral speed is the important point to keep in mind if the sawteeth are to be studied as they cut and remove wood. Films illustrating this point show that a great deal of camera speed is needed to slow the teeth down effectively.

Although it doesn't often happen, it is possible to use too high a taking speed for certain subjects. If this is done, then the projected film will show the action moving too slowly to hold the audience's attention.

When a high-speed film record is made of a timber test it is often desirable to have graphic or electrical data superimposed upon the action frames. This can be accomplished by the use of partial transmission mirrors which allow the reflection of an oscilloscope trace or other recording device to be directed into the lens. The reflections can be focused on a portion of the picture area that will not obscure the primary image.

The camera user runs up against new obstacles with practically every new subject he attempts to photograph. For example, a serious deterrent to getting satisfactory footage of chain-saw teeth in operation was the exhaust from the chain-saw engine. The fumes were so dense that the subject was lost in a cloud of smoke.

In relatively low-speed studies of the leg movement of the centipede, it was found that the animal could not withstand the dry heat of the high intensity lights for more than a second or two. Of course, this problem had to be given serious consideration after several of the centipedes were lost.

General Considerations

Considerable planning should be done before selecting the model of high-speed camera to purchase. While we use the Wollensak Fastax Camera at the College, other makes of high-speed equipment are available and should be investigated. Anticipated use for the equipment will govern the choice in most cases. If speed greater than 10,000 frames per second will not be necessary, then the 16 mm. model Fastax can be considered. If the high-speed motion pictures being produced are to be used with standard-speed footage, the 16 mm. Fastax would probably be a better investment because the films can be spliced together. A large proportion of the films being made for teaching and television are photographed on 16 mm. film.

Film economy is usually considered in the preparation of high-speed motion pictures because large quantities are expended in a short time. The 8 mm. Fastax has the advantage over the 16 mm. model in film consumption since two runs can be made on one roll of 16 mm. film. Another method of saving film is to use 50-foot spools instead of 100-foot ones. This practice is not recommended by the manufacturer nor is it always possible because of the nature of the event. The camera does not reach full speed until 25 or 30 feet of film has been exposed so that only 20 to 25 feet of pictures at the desired taking rate would result on a 50-foot spool.

Most of the items necessary for equipping a high-speed laboratory have been mentioned in this discussion but nothing has been said about projection and editing equipment which is used in viewing the films made with the high-speed camera. Standard 8 mm. projectors and action editors may be used for the 8 mm. films, but 16 mm. equipment must be used for the double width 8 mm. stock. When the latter is projected, two frames will appear on the screen at one time unless the projector is rebuilt for this frame size. Film rewinds, a splicer and an action editor are important accessories for the selection and preparation of footage for projection. Very rarely is the entire 100 feet of a film run usable so it should be edited to save time in projection. This equipment is also necessary if films are to be prepared for class or meeting use.

A Note on Recent Developments in Analytical Aerial Triangulation

D. W. G. ARTHUR,
Photogram. Group, Ordnance Survey, Chessington, England

RECENT literature on analytical aerial triangulation published in the U.S.A.* shows some interesting trends which are deserving of comment since they involve details of technique which have yet to be clarified. The principal features of the new methods are (1) new observation techniques, some of which are linked to 3-table comparators, and (2) new computation methods with greater generality and a more rigorous approach to the handling of the data. Both of these methods seem to imply somewhat greater costs in the instrumentation, observations and computations. The question thus arises, for organizations which are cost-conscious, whether these innovations will be found worth while.

In these new methods considerable importance is attached to the identification of the same point on several photographs. It is widely realized, of course, that certain difficulties exist when more than two photographs are involved. These arise from the essential character of stereoscopic vision as a one-to-one correspondence process between *two* image arrays. If stereoscopic observers had as many eyes as are required to scan simultaneously all the photographs on which the point is registered, then the problem would not exist. However, the photogrammetrist must take things as they are, and adapt his techniques to the limitations of binocular vision.

The classical method of stereo-observation achieves a solution within these limits by marking the point on one of the photographs involved. This is illustrated as follows. Suppose the point is imaged on photographs $a, b, c \cdots m \cdots$ and is marked on photograph m. The point may be co-ordinated on m by simple monocular pointing not involving stereoscopy. It is co-ordinated on all the other photographs by pairing them in turn with the marked photograph and by using stereoscopic transfer. Thus the pairs $ma, mb, mc \cdots$ are observed for this point, but such pairs as ab, ac, bc, are not, and in fact these cannot be observed. In strip triangulation a pass point marked on photograph 2 is observed in the pairs 12 and 23, but not in the pair 13. If, in addition, this point is a tie registered on the photographs of the adjacent strip then photograph 2 is paired with these in turn so that the point is co-ordinated on the photographs of the other strip. The classical solution thus appears to be adequate, and can be achieved with the normal 2-table comparator.

The 3-table instrument makes possible observing the alternate pair 13. Schmid has suggested that this is advantageous. Putting aside his suggestion for the moment, there will be considered the problems of using the pairings 12, 23 and 13, for a pass-point registered on the consecutive photographs 1, 2, 3. The point may be marked on 2, or its position may merely be indicated by the half-mark of the telescope system associated with photograph 2. First, in the pair 12, the parallaxes may be removed by movements of photograph 1. Then switch-

* (a) Schmid, H. Panel Discussion, "The Future of Analytical Aerial Triangulation." PHOTOGRAMMETRIC ENGINEERING, XXIV, No. 1, p. 91, March 1958.
(b) Zurlinden, R. "Conditions to be fulfilled by a Rational System of Analytical Aerial Triangulation." PHOTOGRAMMETRIC ENGINEERING, XXIII, No. 4, p. 659, September 1957.